RESEARCH ARTICLE

UNDERSTANDING ADOLESCENT ACNE: CAUSES, TREATMENTS, AND MORE

Ann Hong[1,2] and Frank Fan[2]

[1]Granada High School, Livermore, CA 94551; [2]Association of Applied Life Science, San Jose, CA 95131

ARTICLE INFO

Corresponding author:
GNADA Noël

ABSTRACT

Acne vulgaris is one of the most prevalent dermatological conditions among adolescents and teenagers, affecting up to 85% of individuals in this age group at least once during their lifetime. Despite its widespread occurrence, many individuals are unaware of the underlying factors contributing to the development of acne. Several specific causes of acne, particularly common in adolescents, include poor dietary habits such as the consumption of junk food and insufficient sleep. The presence of acne can significantly impact an individual's quality of life, often leading to a decrease in self-esteem. To address the high incidence of acne among adolescents, numerous advancements in treatment and technology have been made. These include the application of Artificial Intelligence (AI) for the detection of acne and the use of laser technology for treatment. This review provides a comprehensive summary of the various causes, treatments, and prevention strategies for acne, with a particular focus on adolescence. The aim is to offer foundational knowledge and highlight recent advancements in the field to support the continued development of effective prevention and treatment methods.

INTRODUCTION

Types of acne in adolescents and prognosis

The types of acne vulgaris commonly seen in adolescents are separated into two categories: non-inflammatory and inflammatory (Table 1).

Non-inflammatory acne: Non-inflammatory acne includes blackheads and whiteheads (Figure 1). A blackhead, or open comedone, appears dark in color due to the oxidation of sebum and dead skin cells within the follicular opening. As an open comedone, it is susceptible to trapping dirt and debris due to the exposed nature of the pore. A whitehead, or closed comedone, forms when a buildup of sebum and skin cells obstructs the opening of a hair follicle, resulting in a small, white bump beneath the skin's surface. Both blackheads and whiteheads are typically small, with a diameter of 1 mm or less[1].

Inflammatory acne: Inflammatory acne lesions manifest as papules, pustules, nodules, and cysts. Papules and pustules are typically observed in moderate cases of acne (Figure 1)[2]. Papules appear as firm, pink bumps without any visible whitehead and are often considered an intermediate stage

between non-inflammatory and inflammatory acne. Pustules are similar in size to papules but contain pus, a thick fluid composed of dead white blood cells, tissue debris, and skin cells. Nodules and cysts represent more severe forms of acne vulgaris. Nodules are generally about 5 mm in diameter, while cysts are larger. Both are wide, lack visible pus, and can be hard and painful. Nodules and cysts are more likely to result in significant scarring of the skin[1].

Prognosis of acne: acne scars: In addition to active acne vulgaris, scarring is a common consequence once the acne lesions have healed. Acne scarring can be categorized into two types: those that result in tissue formation and those that lead to tissue loss from the skin. Acne scarring can significantly impair the quality of life for patients, as it is often more challenging and time-consuming to treat[3].

Hypertrophic and keloid scars are both associated with excessive collagen deposition, resulting in tissue formation within the skin. Hypertrophic scars present as areas of increased firmness and may also exhibit dyspigmentation at the site of the wound. Keloid scars are characterized by marked hypertrophy of the skin tissue and are often accompanied by dyspigmentation, similar to hypertrophic scars[4]. Other forms of scarring involve tissue loss in the skin, such as ice pick, rolling, and boxcar scars. Ice pick scars are deep, narrow indentations typically caused by severe inflammatory

breakouts, such as deep papules or cystic acne, and are commonly found on the cheeks. Rolling scars result from the formation of fibrous bands of scar tissue beneath the skin, giving the skin a rolling or uneven appearance. Boxcar scars are round or oval depressions that can appear dark or red. Among these common types of scarring, ice pick scars are particularly challenging to treat due to their deep, sharp indentations in the skin[3].

Prevalence of acne in adolescents and the causes

Acne vulgaris affects all ages and ethnicities but has its highest prevalence in adolescents. There are many reasons why adolescents seem to suffer from this disorder more than others. Acne vulgaris affects individuals of all ages and ethnicities, but it is most prevalent in adolescents. Several factors contribute to the higher incidence of this condition in adolescents compared to other age groups.

History of acne in adolescents: Acne vulgaris has been one of the most common dermatological disorders since ancient Greek and Egyptian times[5] (Figure 2). The Greek physicians Aristotle and Hippocrates would describe acne as a disorder associated with puberty[5], supporting the fact that many adolescents have historically always had acne. In 1931, dermatologist Bruno Bloch was the first in modern times to recognize that acne, particularly in the form of comedones, could be considered a physiological manifestation of puberty due to its high prevalence among teenagers[6]. While acne is now better understood, misconceptions still persist regarding its treatment and pathogenesis.

Prevalence of acne: According to the Global Burden of Disease (GBD) study, acne vulgaris affects approximately 85% of individuals aged 12 to 25 years[7]. It is one of the most prevalent dermatological disorders among adolescents, with estimates suggesting that 85% of teenagers will experience acne at some point[8]. In an analysis of acne prevalence across different age groups in mainland China, the overall rate of acne among students and undergraduates aged 7 to 23 years was found to be 39.2%, with a variation of 10.2% across different age groups. The prevalence was highest among primary school students (ages 7-17), with a rate of 50.2%, followed by undergraduates at 44.5%. Additionally, male students exhibited higher rates of acne compared to their female counterparts, and individuals in Southern China had higher prevalence rates than those in Northern China[9]. This suggests that geographic factors also influence the prevalence of acne.

Causes of acne in adolescents

Hormonal changes during puberty: One of the primary causes of acne in adolescents is hormonal changes that occur during puberty. During this period, sex hormones, primarily androgens, are secreted, which stimulate the sebaceous glands to produce an excess amount of sebum due to glandular overstimulation and enlargement. This excess sebum can contribute to the development of acne[10,11]. A study conducted between 2008 and 2009 examined patients around 20 years old with moderate to severe acne to assess their levels of testosterone, luteinizing hormone, and follicle-stimulating hormone. The results revealed that all patients with acne had slightly elevated testosterone levels compared to individuals without acne, regardless of gender.

Unhealthy diet: Apart from hormones, the diet consumed by adolescents will also add to the inflammation present on the skin. Especially with a Western diet, teenagers typically will consume more sugary foods, refined grains, high-fat dairy products, and high-sugar drinks. These are all high-inflammatory foods, while teenagers tend to eat fewer vegetables and foods high in fiber, which are foods that will actually help fight inflammation. The Western diet is also becoming increasingly common in developed countries and also in developing countries. The glycemic index (GI) is a system of classification where the glycemic responses of foods are indexed against standard white bread. The GI shows how quickly foods will affect an individual's glucose level when that food is eaten by itself[12]. Foods with a high GI will further acne genesis and escalate the severity of acne[13].

Mental health: Another main cause of acne in adolescents is the high amount of stress and anxiety that teenagers face in their daily lives. This stress and anxiety comes from being in unfamiliar environments, applying for college, and the large amount of testing. High levels of stress will affect the skin through the Hypothalamus-Pituitary-Adrenal (HPA) axis, causing the Corticotropin-Releasing Hormone (CRH) to be released, which causes increased sebum production. This will block the sebaceous filaments, causing acne[14].

Additionally, stress induces cytokines production in keratinocytes, which contributes to inflammation.[15] A study conducted in 2007 studied the impact of psychological stress to find out if it increases sebum production, which in turn will cause acne. Ninety-four students in Singapore with a mean age of 14.9 were enrolled in this study. The prevalence of self-reported acne was high, with a 95% rate in males and a 92% rate in females. The study showed significant association between stress and acne vulgaris in adolescents, especially in males[16].

Abnormal microbiome: Recently, studies have shown that the microbiome is another main factor in the development of acne. The microbiome alludes to bacteria, viruses, and fungi along with their environment. The composition of the microbiome depends on the individual's skin physiology, which can be changed by many factors, including humidity, dryness, and sebaceous content[17]. The bacterium that causes acne on the skin is called *Cutibacterium acnes*, an anaerobic major commensal bacterium that appears in the common skin flora but also contributes to the pathogenesis of acne. However, acne does not appear because of a large amount of *C. acnes*, but instead when there is a loss of diversity between the balance of multiple strains of the bacterium[17].

Smoking and nicotine-containing products: Smoking is also linked to many causes of acne vulgaris, as smoking will cause an increase in the grade of sebum peroxidation while the amount of vitamin E will decrease[18]. Sebum peroxidation lowers the level of oxygen available in the lipid, which makes it a place for anaerobic bacteria such as *P. acnes* to thrive. The lessening of vitamin E means that there are fewer antioxidants contained in the skin, which will cause acne patients to experience high levels of systemic inflammation[19]. This could be a strong cause in the pathogenesis of acne in adolescents because adolescents smoke or consume products created by nicotine, such as vapes.
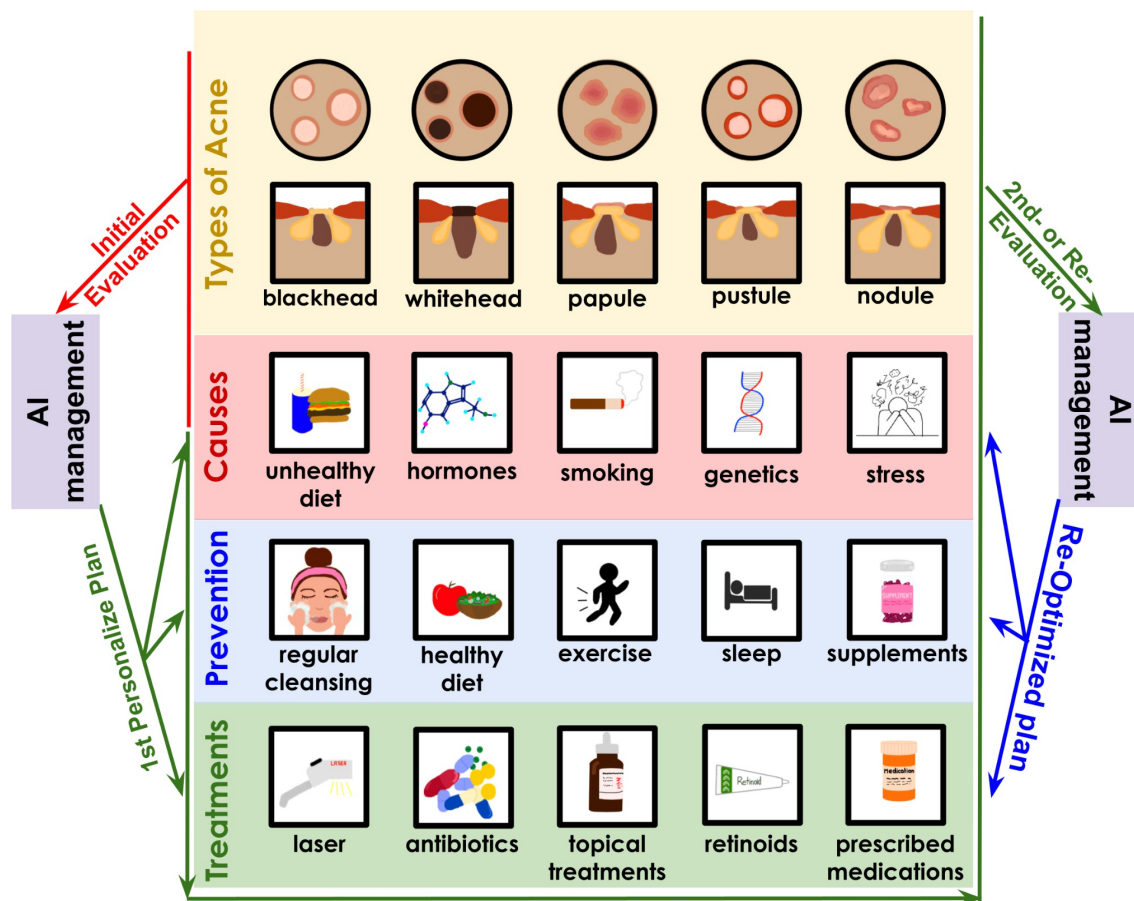
Figure 1. AI assisted personalized prevention and/or treatment optimization system for acne
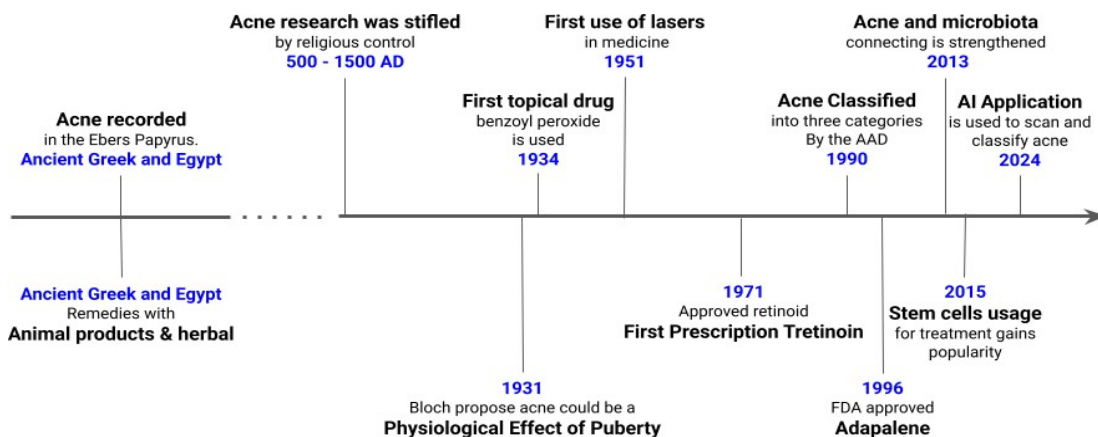

Figure 2. Timeline and major events for the acne studies and its treatments

Treatments for acne

Varieties of treatment for acne vulgaris have been developed over the years, especially with the tech advances, new treatments are emerging with high potential. (Table 2).

Topical Treatments

Retinoids: Some of the most popular and most effective products for acne are topical retinoids. Retinoids are a class of chemical compounds that come from vitamin A. Topical retinoids will eliminate mature comedones, reduce lesion formation, and also provide anti-inflammatory effects. Some adverse effects such as erythema, dryness, itchiness, and stinging occur frequently during the initial treatment phase, but mostly stop occurring during the course of the treatment[20].

Among the most frequently used topical retinoids, tretinoin has been shown not to possess direct antibacterial properties, but it can induce changes in the skin microbiome in acne patients. A small study conducted in 2024, primarily involving young female subjects with mild acne, found that after approximately 90 days of tretinoin treatment, there was a relative abundance of *Kingella*. Additionally, the therapeutic effects of tretinoin persisted for up to 60 days after discontinuation of the treatment[21]. Tazarotene, also another common topical treatment, is a receptor-selective retinoid which is used for the treatment of acne, psoriasis, and photo-aging. It has also been shown clinically that 0.1% tazarotene will have a better effect on acne than 0.025% tretinoin gel[22]. Adapalene is also a topical retinoid that has the ability to control cellular differentiation on

the skin. Depending on the cell type, the modulation can result in the promotion or inhibition of differentiation[23].

Non-retinol topical treatments: A non-retinoid topical treatment used for acne vulgaris is benzoyl peroxide. A study conducted in 2019 found the impact that benzoyl peroxide had on preadolescent acne in girls. The fifty-one participants used a 4% benzoyl peroxide face wash for 6-8 weeks, and found that acne counts had decreased[24]. Salicylic acid is a non-retinoid topical treatment that works by helping the skin to shed dead cells from the top layer and reduces inflammation and redness.

This decreases the number of acne vulgaris that appears on the skin, and increases healing. Azelaic acid is a naturally occurring dicarboxylic acid usually used for the treatment of comedonal and inflammatory acne. In controlled studies, azelaic acid has comparable anti-acne properties comparable to those of benzoyl peroxide, tretinoin, and erythromycin[25]. Many essential oils have been found to have healing and anti-inflammatory properties, which are beneficial for acne, especially for inflammatory types of acne. These oils have been found to have anti-inflammatory, antioxidant, and antimicrobial properties, which can prevent the different causes of acne[26]. Essential oils could be a promising approach to treat acne vulgaris because of their strong ability to penetrate deeply into the skin, and reach the deeper layers[26]. Specifically, tea tree oil is one of the most well known essential oils, and it has various properties that fight and prevent acne causing bacteria[27].

Nanoparticles application in acne treatment

Photothermal nanoparticles: Nanoparticles are sphere shaped particles made of either natural or synthetic polymers. They have a wide variety of applications, and one of them is acne vulgaris treatments. Photothermal treatment is a popular way to incorporate nanoparticles into acne treatments. In a 2021 study on photothermal therapy using gold nano-particles, 12 patients with moderate to severe acne received three treatments with one to two week intervals. Significant reduction in acne lesions was shown, and using the Physician Global Assessment, the patients had an average improvement of more than 50% in their acne[28] .

Nanoparticles as carriers: Some acne treatments incorporate nanoparticles as a delivery or carrier system to enhance the targeted action of the treatment and control the release of the active ingredients. One such approach involves the use of solid lipid nanoparticles to load acne treatments. For example, a formulation containing neem oil was encapsulated in solid lipid nanoparticles to prevent acne and pimples while also improving skin elasticity. The entrapment efficiency of the solid lipid nanoparticles was found to be 82.10%, indicating that the nanoparticles are capable of holding a significant amount of neem oil[29].

Nanoparticles loaded with retinoic acid: In 2006, a solid lipid nanoparticle treatment for acne vulgaris was formulated, containing retinoic acid as a topical acne treatment. The solid lipid nanoparticles containing all-*trans* retinoic acid have potential for controlled penetration of the skin follicles. The results show that the utilization of amines is an interesting approach to improve the encapsulation efficiency of retinoic acid in solid lipid nanoparticles using a low surfactant and lipid ratio[41].

Stem cell-related application in acne treatment

Stem cells as a coating carrier: Stem cells are precursor cells that are present in many tissues and have the ability to differentiate into many different cells. An example of this is using stem cells for a membrane-coated isotretinoin. Isotretinoin is one of the most potent forms of acne treatment, however it has many side effects that limit its full potential. For example, isotretinoin by itself is not able to fully penetrate the stratum corneum, which is the most important layer of the skin. By using stem cell membranes to coat the isotretinoin, it was able to provide much more therapeutic effects[30].

Stem cells for acne scarring: In addition to treating active acne, stem cells can also be utilized in the treatment of acne scarring. A study conducted over two months involving the use of human stem cell-conditioned media (HSCM) following CO_2 laser treatment for atrophic acne scars and skin pores demonstrated significant improvements. The results showed a 23.5% reduction in scar volume and a 37.6% increase in skin pore volume. Both scars and skin pores improved by at least 15.0% in the areas where HSCM was applied, indicating that this treatment method yields promising results[31].

Laser therapy for acne: In a 2006 study of pulsed-dye laser therapy was used to find in vivo effects of short pulse duration non ablative pulsed-dye laser (NA-PDL) on cytokine production, *P. acnes* colonization amount, and the sebum excretion rate (SER). The scientist used a scrub-wash technique and culture, and on cytokine mRNA using reverse transcription-polymerase chain reactions from skin biopsies. The laser decreased many acne lesions, and NA-PDL provides a possible unifying molecular mechanism linking stimulation of dermal remodeling in photorejuvenation with inhibition of inflammation in acne[33].

Oral Treatments

Drugs

Doxycycline: Doxycycline is an oral antibiotic classified as a tetracycline. It is a bacteriostatic agent that works by inhibiting bacterial ribosomes, thereby preventing protein synthesis in bacteria. Doxycycline is well-absorbed and exhibits good tissue penetration. Its effectiveness in treating acne vulgaris is partly due to its antibacterial properties, particularly against *Propionibacterium acnes* , a key pathogen in the development of acne [34] .

Isotretinoin: Isotretinoin, commonly known by the brand name Accutane, is one of the most potent treatments for acne. Typically, patients do not require further acne medications after completing an isotretinoin regimen. While isotretinoin does not possess antimicrobial properties, it effectively alters the microenvironment within the pilosebaceous unit by reducing sebum excretion rate (SER) and decreasing the size of sebaceous glands. These actions contribute to its efficacy in treating acne[35].

Other oral treatments

Oral probiotics: A new and emerging treatment used for acne is oral probiotics. Probiotics were first discovered in 1907 by Elie Metchnikoff and found a strong correlation between the bacteria that produced lactic acid and longevity[36]. Oral

probiotics show their effect on the skin through various mechanisms, such as reduction of systemic inflammation and influence on absorption[37].

The available preventions

Healthy lifestyle: Having healthy habits and managing risk factors are extremely important for preventing acne in adolescents[31]. Healthy habits for teenagers include consuming healthier foods and keeping a good diet, increasing the amount of physical activity, and staying away from drugs[32]. Eating unhealthy foods, not exercising, and consuming illegal substances are all especially prevalent in young adults, and can lead to not only acne vulgaris, but other health related disorders and diseases such as obesity, depression, and anxiety.

Vaccines for Acne: Vaccine-based approaches for the treatment of *Propionibacterium acnes*-associated inflammatory acne vulgaris have been explored, focusing on two primary candidates: a cell wall-anchored sialidase derived from *P. acnes* and killed whole organisms of *P. acnes.* A vaccine developed in 2008 utilized these approaches, incorporating either the sialidase or killed whole organisms of P. acnes. Subsequent studies have indicated that such a vaccine could prevent the onset of acne vulgaris or reduce its severity compared to untreated cases. However, targeting *P. acnes* may disrupt the skin microbiome, which plays a crucial role in maintaining skin homeostasis. Despite this, the development of an acne vaccine remains a promising avenue for further investigation and optimization[63].

New Tech Applications in adolescent acne diagnosis monitoring, and treatment assist. Advanced modern technology has made it possible to diagnose acne much more easily compared to in-person appointments with a patient.

Smart care for acne: the application of Artificial Intelligence. The use of artificial intelligence (AI) for the detection and treatment of acne vulgaris has seen growth in recent years, paralleling the adoption of AI across various sectors, including healthcare, education, business, and commerce. AI began gaining traction in the 1980s and has since evolved into a versatile tool with applications in diverse fields.

In dermatology, AI has been integrated into mobile applications designed to automatically detect acne on the face and assess its severity. One such system, AcneDet, utilizes AI to scan facial skin for acne and grade its severity according to the Investigator's Global Assessment (IGA) scale. The convenience of AI-powered mobile applications enables users to assess their skin at home, increasing accessibility and fostering widespread use. In addition to grading acne severity, AI systems employing deep learning algorithms have been developed to predict acne outbreaks by detecting irregularities on the skin, providing users with proactive skin care insights. These advancements in AI, particularly in object detection, have greatly enhanced the accuracy and functionality of acne detection systems on mobile devices[9]. Another promising AI technology is machine learning, which has emerged as a key development in the medical field, particularly in the field of imaging. Machine learning models, leveraging large image databases, can diagnose various forms of acne vulgaris by analyzing clinical photographs, dermoscopic images, and histopathological slides. Studies have demonstrated that machine learning models for acne diagnosis can achieve

diagnostic accuracy comparable to, and in some cases exceeding, that of board-certified dermatologists. This highlights the potential of AI in improving the efficiency and precision of dermatological diagnostics[40].

CONCLUSION AND PERSPECTIVE

Acne is one of the most prevalent skin disorders affecting adolescents, manifesting in various forms and exerting both physical and psychological impacts. Over time, preventive measures, treatments, and innovative technologies have evolved to address this condition. Notably, recent advancements in dermatology, including the integration of AI and probiotics, have contributed significantly to the understanding and management of acne. One of the most probable future acne treatments lies in the AI field (Figure 2). AI can first assist with acne evaluation, identify the cause and diagnosis, then form a set of personalized treatment plans which might include nutrition, supplements and new drug application. Then, the AI management system would monitor the outcomes of the treatments, and optimize the plan and send out the modified instructions. The system will then monitor changes to decide whether to modify or stay with the treatment. This would be a more personalized and effective way benefiting both the patient and doctor, and would be incredibly valuable for adolescents.

Conflicts of Interest: The authors declare no conflict of interest.

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